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ENGINEERING REPORT NO. 11006

ADVANCED FIGURE SENSOR
OPERATIONS AND MAINTENANCE MANUAL

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GODDARD SPACE FLIGHT CENTER

GLEN DALE ROAD

GREENBELT, MARYLAND 20771

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**Details of illustrations in
this document may be better
studied on microfiche**

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1.0 INTRODUCTION

1.1 SCOPE

This manual contains procedures for installing, operating, and maintaining the optical figure sensor and its associated electronic controls. The optical figure sensor, a system of integrated components, comprises (1) a phase measuring modified Twyman-Green type interferometer employing a single frequency 6328A Model 5800 Perkin-Elmer Laser, and an ITT Cannon F5005 Vidi-ssector, (2) a two-axis automatic thermal compensation control mount, (3) a five degree of freedom manual adjustment stand, and (4) a control console. The instrument is shown in Figure 1. The purpose of this instrument is to provide real time output data of optical figure errors for spherical mirrors also capable of measuring aspherical mirrors if a null corrector is added.

The figure sensor interferometer optics, laser, and image dissector are all mounted to a rigid one-inch thick optical baseplate within the instrument. The optical baseplate in turn is mounted to a two-axis parallelogram system of flexure blades that allows it to translate in the x and y directions about the line of sight (LOS) to automatically compensate for thermal variations of the test mirror. Each axis of the flexure blade translation mount is driven by a single thermal compensator actuator that operates from electrical signals developed by the photosensors, i.e., an image dissector or photodiodes. The figure sensor interferometer assembly, the optical base, and two-axis thermal mount are housed in a rigid box-shaped aluminum structure complete with front and rear access covers as shown in Figure 1. The optical base layout is shown in Figures 2 and 3. The outer structure of the figure sensor assembly mounts onto the external manual adjustment stand. The major portion of the electronics, including power supplies, instrumentation, and controls is located in the vertical equipment rack or control console.

1.2 APPLICABLE DOCUMENTS

The information required to maintain and operate the Perkin-Elmer

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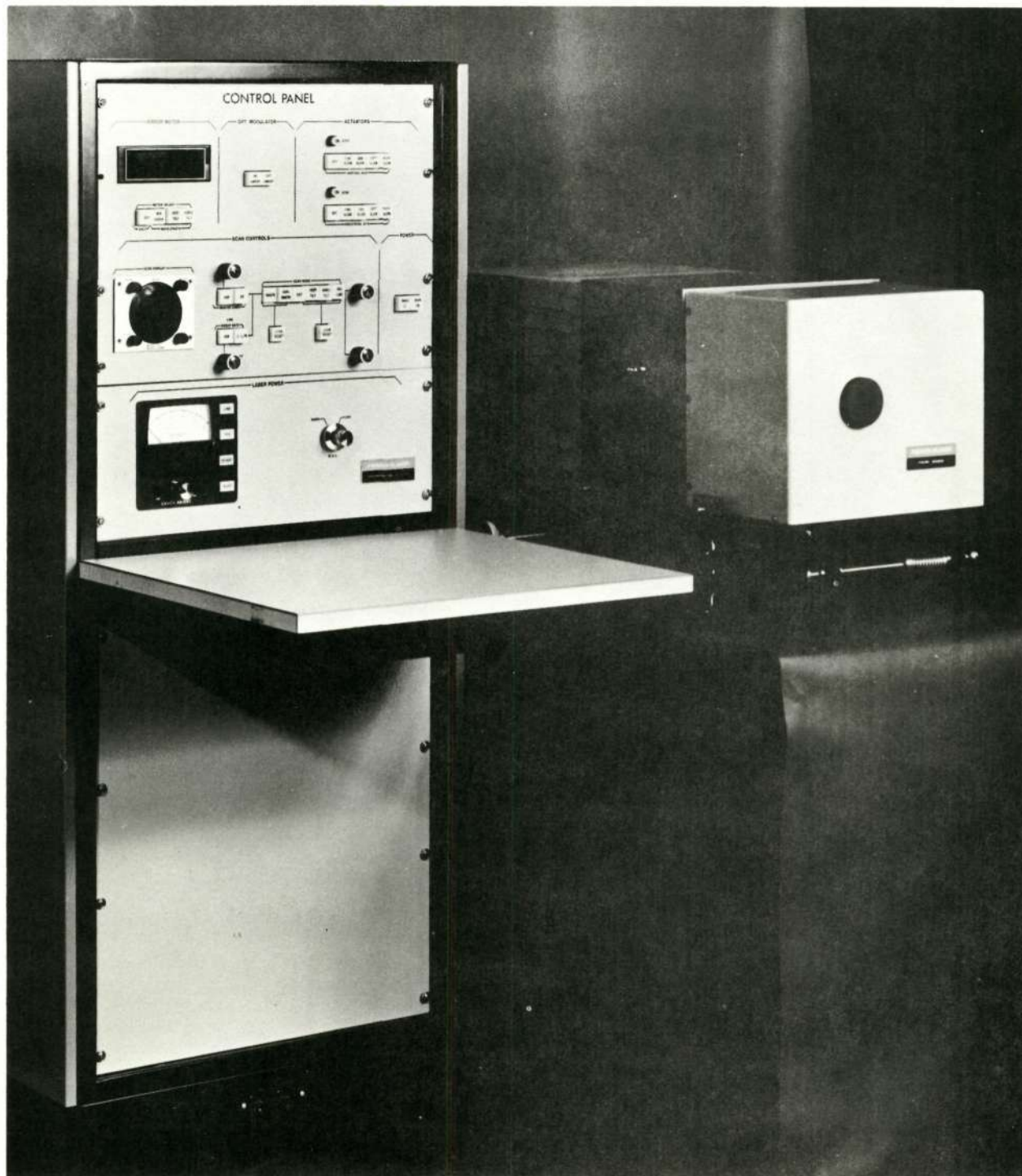


Figure 1. Real Time Figure Sensor

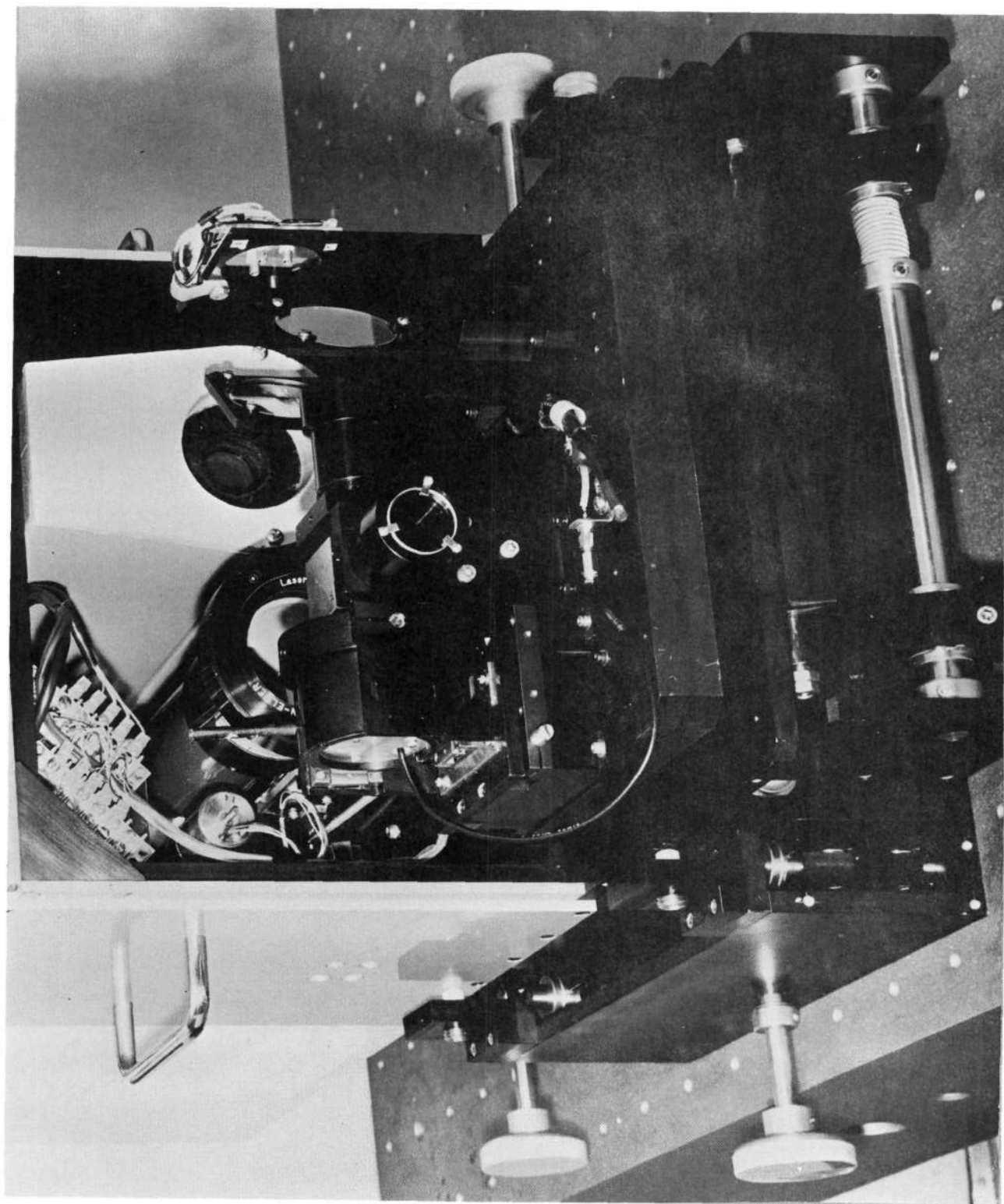


Figure 2. Optical Base

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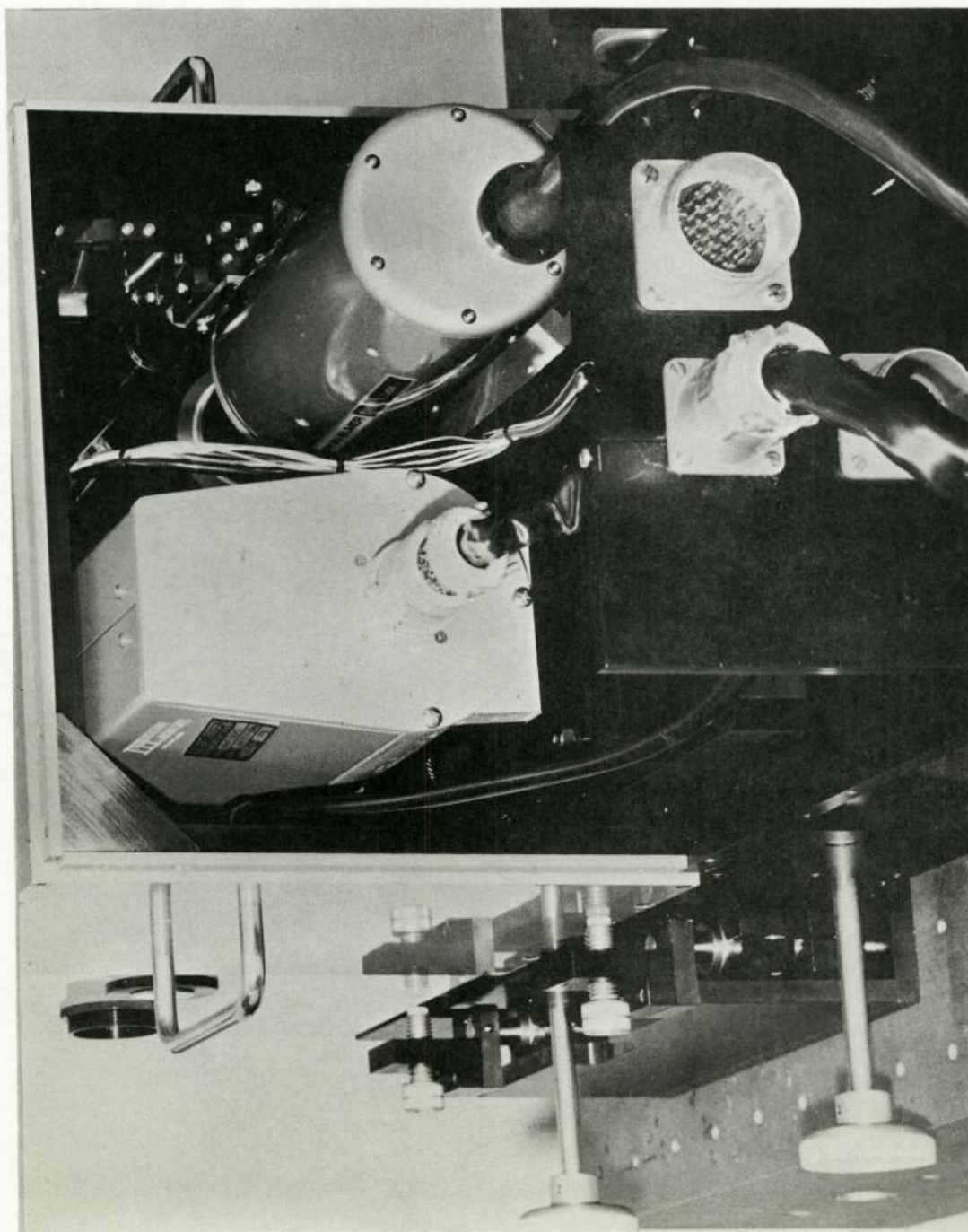


Figure 3. Optical Base

model 5800 laser and the ITT Cannon F5005 Vidisector Camera and control unit can be found in the two manuals, listed below:

- Perkin-Elmer Instruction Manual No. 450-0008
Model 5800 Single Frequency Laser
(June, 1967; Revised February, 1968)
- ITT Cannon Instruction Manual

1.3 SAFETY PRECAUTIONS

The following safety precautions should be observed when operating the instrument.

Use care whenever the Model 5800 laser or the Model 5801 laser power supply is operated without its protective cover or screen. It is noted however that the laser output beam is normally expanded by 20x in the figure sensor by a beam expander which is attached to the output end of the laser and in this case, the danger of damage to the eye is practically non-existent. However, extreme caution is recommended when viewing any of the three figure sensor interferometer laser focal points. The output of the decollimating lens and the center of the relaying imaging lens are high intensity points that, when viewed directly, require the use of special safety glasses.

Use care whenever operating the figure sensor interferometer with the front and rear covers removed, to avoid contact with the optical modulator high-voltage terminals.

2.0 INSTALLATION

2.1 HANDLING PROVISIONS

The figure sensor assembly is equipped with two handles (see Figure 1) capable of supporting the entire assembly including the manual adjustment stand. During handling it is recommended that the interferometer optical baseplate be secured to the outer side plates of the figure sensor with spacer blocks to prevent damage to the thermal mount linkages and actuators. The four manual adjustment stand locks should also be secured during handling.

The control console is supported upon casters and can be easily transported.

2.2 MOUNTING PROVISIONS

The manual adjustment stand contains four 3/4 - 28-inch tapped holes on its baseplate for mounting purposes. The figure sensor assembly and adjustment stand are capable of being mounted both horizontally and vertically⁽¹⁾ (pointing downward).

NOTE: The manual adjustment stand can also be removed from the figure sensor assembly. The mounting provisions, a front mounting hole and four rear mounting holes normally used to attach the adjustment stand to the figure sensor, can then be used for mounting the figure sensor assembly.

2.3 ELECTRICAL CONNECTIONS

The following electrical connections are required (see Figures 3 and 4).

(1) The figure sensor interferometer less adjustment stand can be mounted vertically pointing both up and down. The manual adjustment stand is limited to supporting loads in only the downward direction because of the arrangement of preloading springs in the focus axis.

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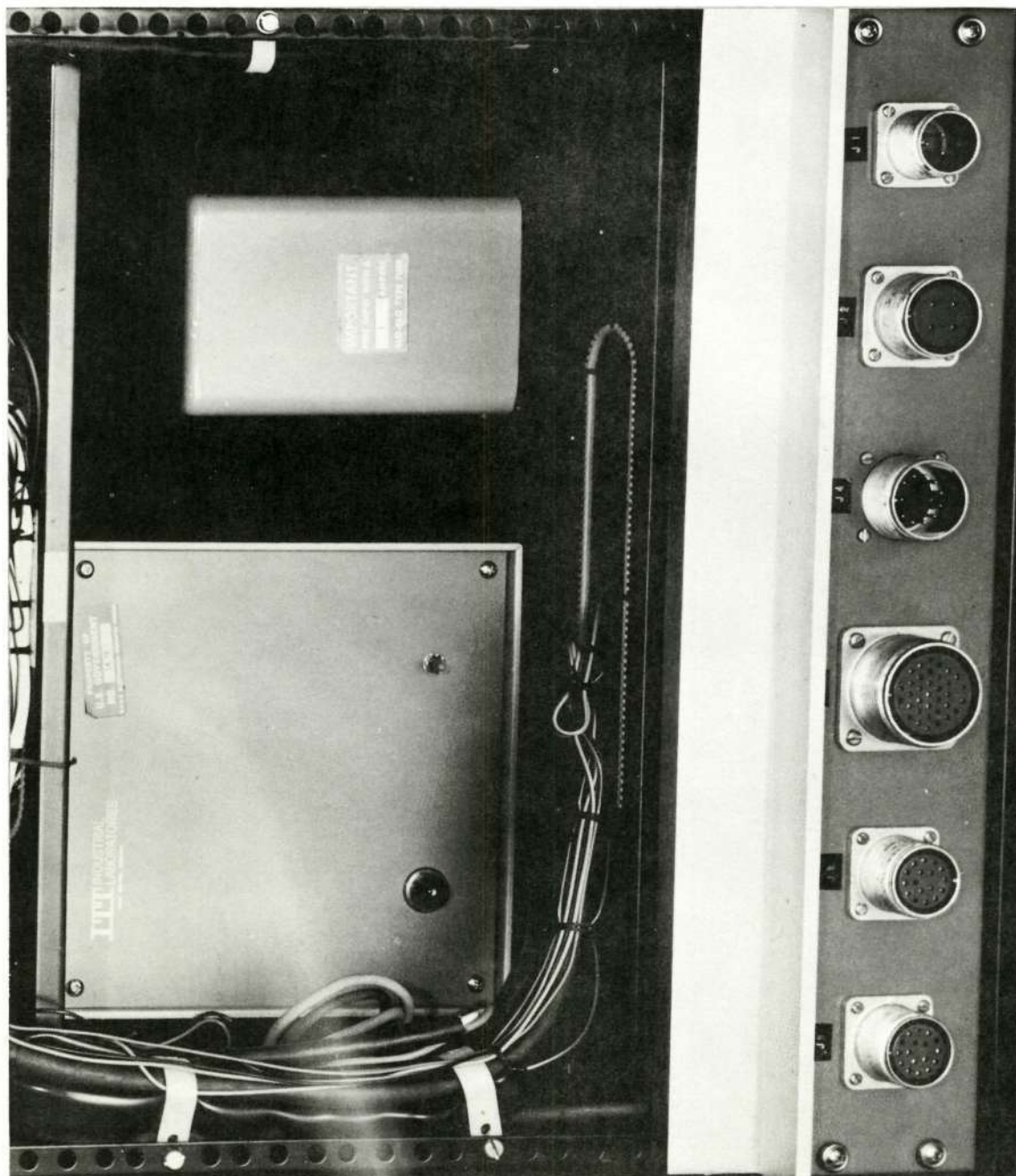


Figure 4. Control Console Rear Connectors

(1) Connect the figure sensor image dissector connector J10 to connector J9 of the control console (lower rear connector panel).

(2) Connect the figure sensor 5800 laser cable connector J5 to connector J4 of the control console.

(3) Connect the actuator and photodiode cable between connectors J7 of the figure sensor assembly and J6 of the console.

(4) Connect the optical modulator cable between connectors J3 of the figure sensor assembly and J2 of the console.

(5) Connect the 115 VAC, 60 Hz cable connector J1 to the console. The following jacks are available at the test box:

- External digital voltmeter inputs
- External optical modulator inputs
- External image dissector scan inputs
- Hewlett Packard 7000 x-y pen lifter signals
- Output signals, raster scan and figure error.

2.4 SPECIAL FACILITIES

Precautions must be taken to isolate the figure sensor assembly and the mirror under test from external mechanical vibrations and air turbulence in order to achieve best performance. Minimization of vibration between the figure sensor assembly and the test mirror is most important. A rigid mounting base common to both the figure sensor assembly and the test mirror and having low frequency vibration isolators supporting the base structure is recommended.

Air turbulence can be sufficiently minimized by shielding the optical path between the figure sensor assembly and the test mirror when the separation between the two is small (1 to 2 feet). However, a vacuum tank

is recommended when the separation between the figure sensor assembly and test mirror is large.

3.0 PRINCIPLES OF OPERATION

3.1 PHASE MEASURING INTERFEROMETER

The modified Twyman-Green interferometer is a two-beam interferometer capable of measuring both spherical and aspherical surfaces. As shown in Figure 5, a plane laser wavefront enters into a beamsplitter, forming two exiting plane wavefronts. One wavefront is referred to as the reference beam and is reflected by a flat reference mirror. The second plane wavefront is the measuring beam and enters into a decollimating lens which creates a spherical wavefront, with focus at Point F, that illuminates the clear aperture of the mirror under test. If the test mirror has a spherical surface and it is aligned so that its center of curvature is located at the center of curvature of the spherical wavefront (Point F), the light will be reflected back exactly upon its incident path. Assuming an identical situation exists for the reference mirror where the reference beam is also reflected back upon its incident path, interference will then take place between the two returning plane wavefronts at the beamsplitter, forming a fringe pattern which exits the beamsplitter.

When there are surface irregularities on the mirror under test, or when it is misaligned, the return wavefront from this mirror will not be perfectly spherical, thus forming irregularities or intensity variations in the fringe pattern when compared with the ideal wavefront from the reference flat mirror.

The variations in fringe pattern intensity (i.e., the test mirror fringe errors) are analyzed electronically to permit real-time error sensing. In practice, this is accomplished by use of the phase measuring technique that operates as follows. The reference reflector is translated at constant velocity along the optical axis normal to the wavefront, by a piezoelectric crystal located in the Doppler frequency shifter assembly. A varying optical path difference between the two interferometer arms will cause the fringe

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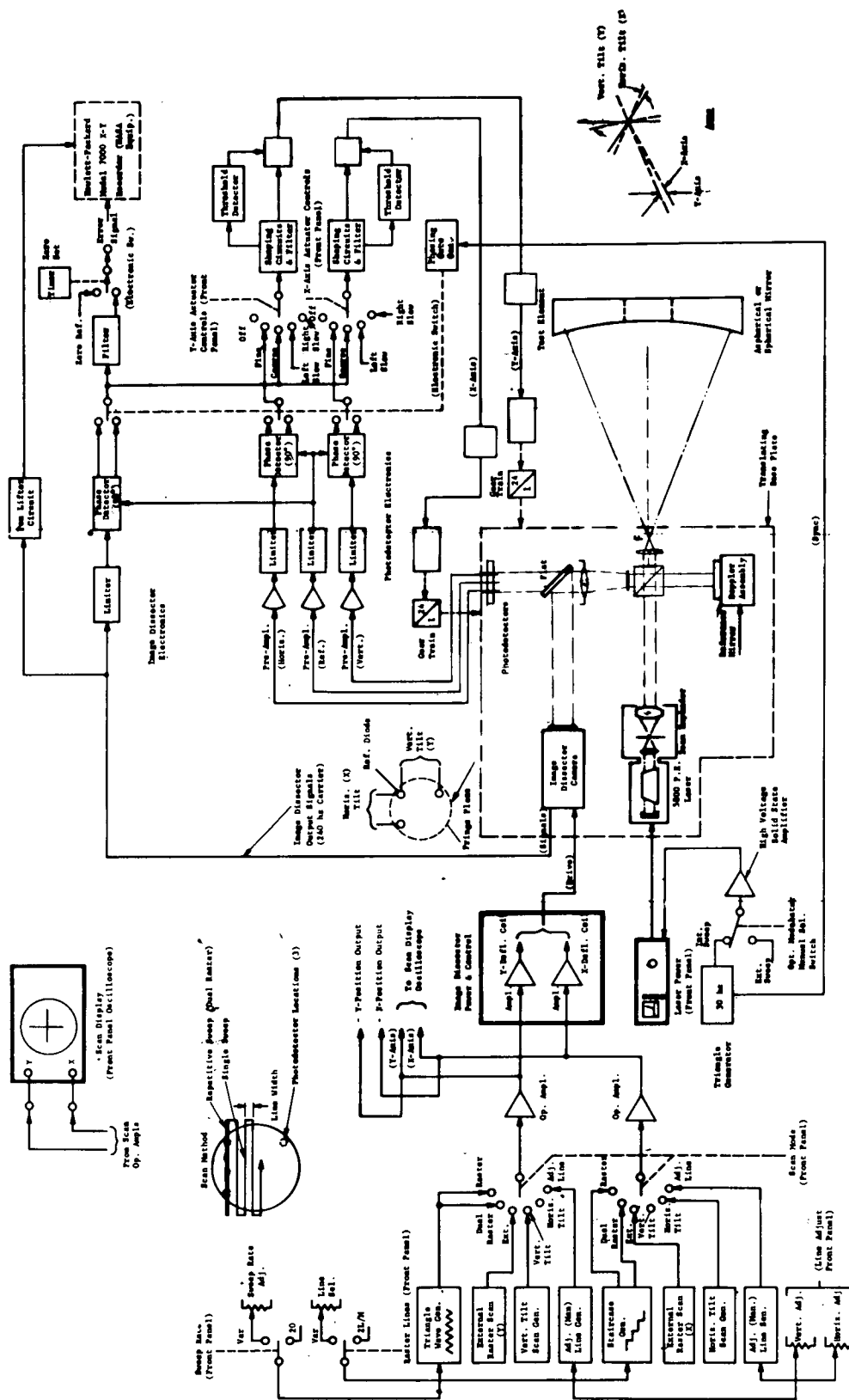


Figure 5. Figure Sensor System Block Diagram

pattern intensity to vary through maximum and minimum levels in a sinusoidal fashion. When two photodetectors are placed in the fringe pattern, one at a position arbitrarily selected as a reference and one corresponding to a spot of unknown figure on the test surface, they convert the cycling fringe pattern into two cycling electronic voltages. If a small portion of the test surface is high in relation to the test of the surface, there will be a relative phase shift of the electronic signal generated from the fringe pattern corresponding to that point on the test surface. Thus an optical figure error is converted to a phase shift of an electronic signal.

Photodiodes and an image dissector are used to convert optical figure errors into electrical signals. Three photodiodes are used to sense test mirror tilt in two axes. The diodes are situated in the fringe plane at moment arms about the axes of mirror rotation. One diode is common to both axes. The image dissector is used to scan every part of the test mirror. The image dissector scanning aperture uses the common photodiode as the reference signal, comparing this signal with the scanning aperture signal to obtain a measure of figure error.

Additional optics are actually required to implement the phase measuring interferometer as shown in the system block diagram of Figure 5. These optics relay the fringe pattern to both the photodiode location and the image dissector cathode surface.

3.2 THERMAL COMPENSATING MOUNT AND OPTICAL BASE

3.2.1 Thermal Mount: The thermal compensating mount was incorporated into the fringe sensor assembly to automatically correct for two-axis angular tilt of the test mirror caused by thermal drifts. Since a test mirror tilt is, for all practical purposes, identical to a translation at the figure sensor assembly for small angles, thermal control is accomplished by translating the figure sensor optical base in two axes using a flexure blade parallelogram.

A partial assembly of the figure sensor is shown in Figure 6 which illustrates the type of construction used for the thermal mount. The

main optical base is suspended on four flexure blades, which allow it to be translated ± 0.01 -inch horizontally. The opposite ends of the inner flexure blades are fastened to an intermediate box-like structure. This intermediate structure is, in turn, supported by four outer flexure blades, which allow it to be translated vertically by ± 0.01 -inch, thus translating the optical base in a vertical direction.

The opposite ends of the outer flexure blades are then attached to the main frame of the figure sensor.

Figure 7 shows one of the thermal compensator actuator subassemblies that are used to drive each axis of the thermal compensating mount. Each actuator drives through a 100:1 linkage using flexure blades for pivots. The linkages reduce the displacement of the optical base per motor step. In addition, the optical base with all components added weighs 50 pounds and when the figure sensor assembly is mounted horizontally, as shown in Figure 1, this weight must be counteracted in the vertical direction. The 100:1 linkage reduces this load to 1/2 pound as seen at the vertical actuator.

The linkages also reduce the stepping increments as referenced to the optical base.

3.2.2 Optical Base: The interferometer components are mounted on a common one-inch thick aluminum baseplate, to assure that optical/mechanical alignment is maintained. Figure 8 is a photograph of the optical base layout, front and rear, and shows the Perkin-Elmer Model 5800 Laser, image dissector, photodiodes, Doppler frequency shifter, and optical elements. The 32 mm beamsplitter is bonded to a 1/8-inch titanium piece that, in turn, is fastened to a center aluminum mounting block. The laser decollimating lens and imaging lens are mounted to the same block. Various reference surfaces have been used on this center mounting block for alignment, as shown in Figure 9. A 70/30

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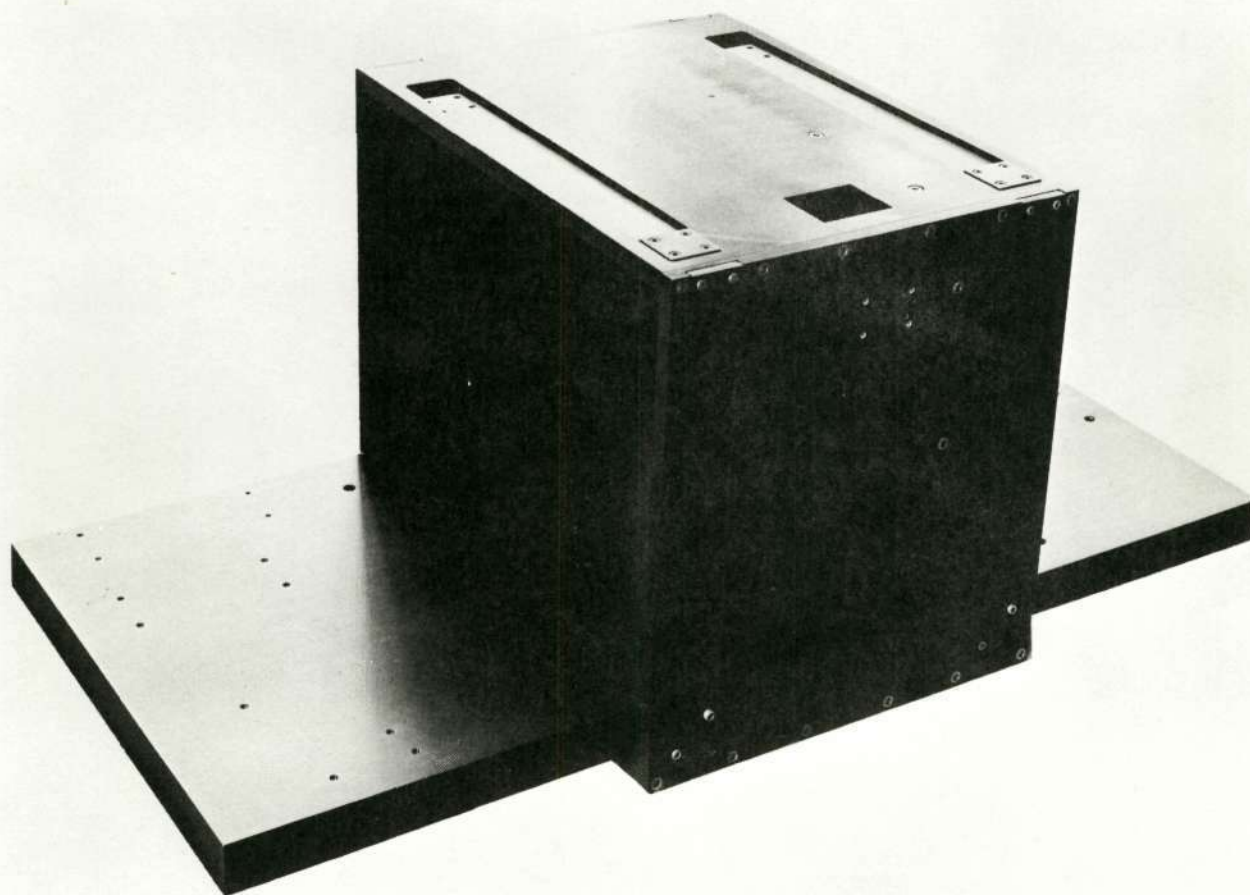


Figure 6. Flexure Blade Parallelogram,
Partial Assembly (One Axis)

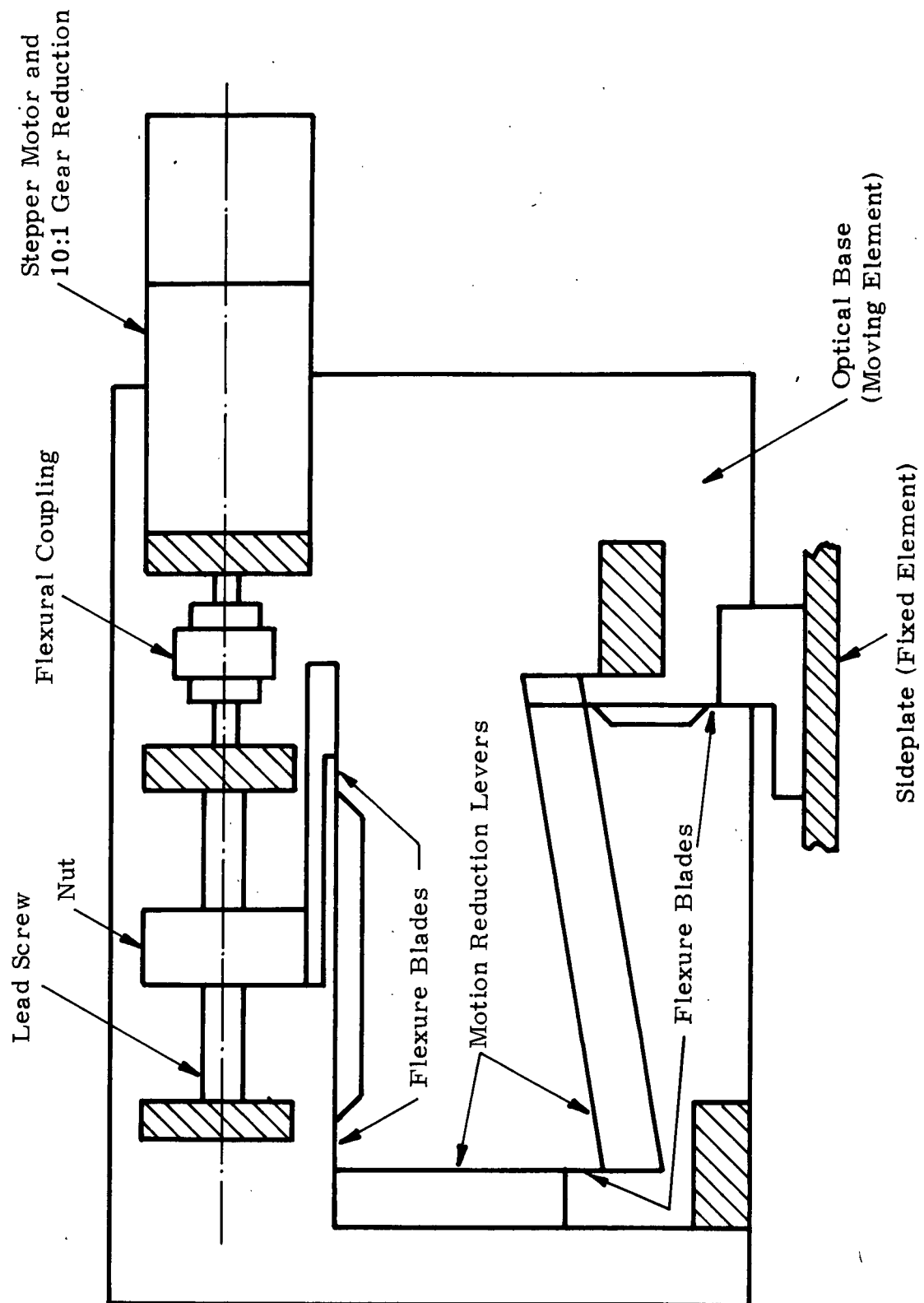
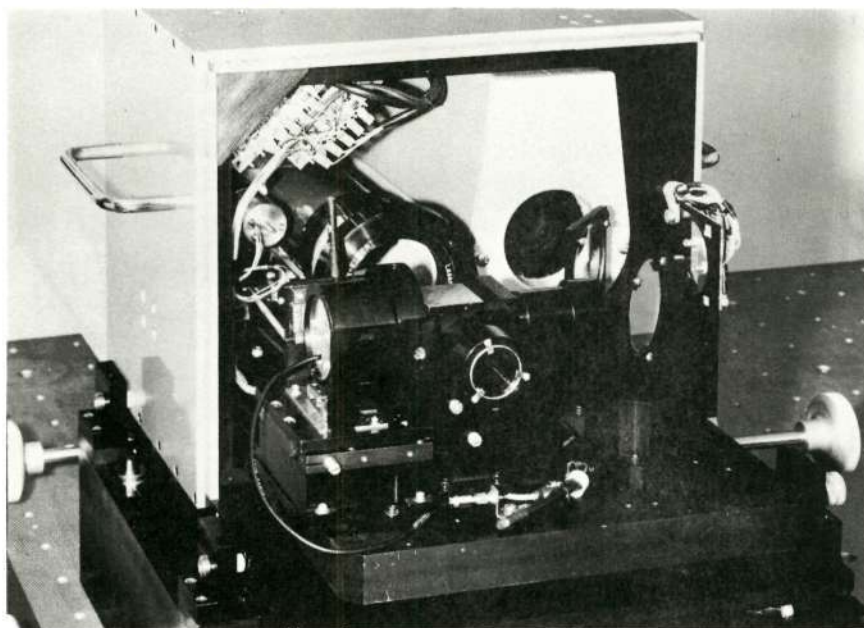
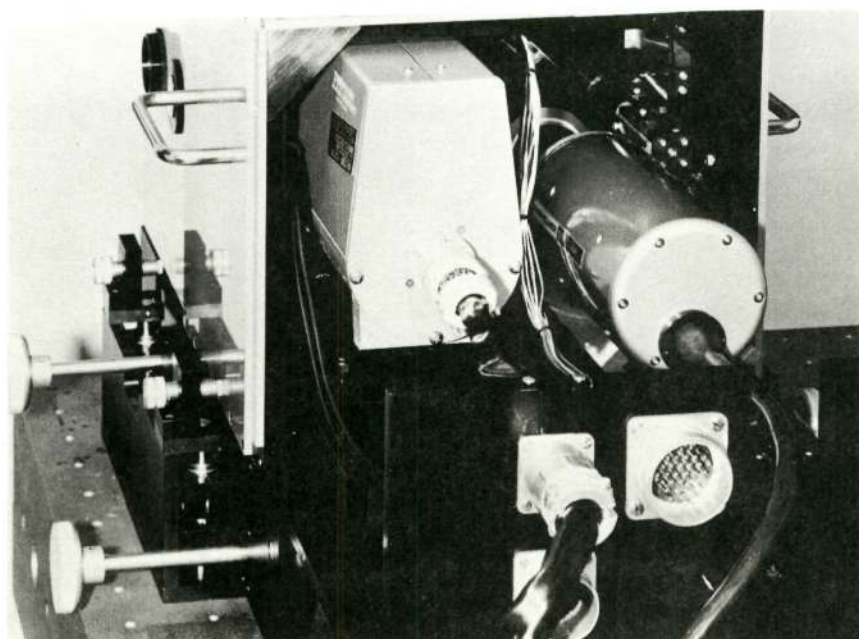


Figure 7. Thermal Compensator Actuator

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(a)



(b)

Figure 8. Figure Sensor Optical Base (Front and Rear Views)

beam divider aligns the main optical path parallel to the laser, which allows the image dissector to be located alongside the laser. Thirty percent of the light passes through the 70/30 beam divider for obscuration or photography of the fringe pattern. A second beam divider sends 30 percent of the remaining light to the photodiodes. The imaging lens images the mirror under test at the image dissector focal plane and at the photodiodes.

Precise mechanical adjustments are provided in several areas. Both the decollimating lens and imaging lens have axial adjustments. The Doppler frequency shifter reference mirror can be adjusted axially and in two angular directions by means of microinch adjustment mechanisms. These miniaturized devices are 1x1x1/8-inch in size, have an adjustment range of 0.02-inch, and are used for positioning to increments as fine as two micro-inches.

All electrical cabling is routed directly from the optical base to the rear connector plate. Cable loops accommodate x and y motions of the optical base.

3.3 LASER, IMAGE DISSECTOR, AND DOPPLER FREQUENCY MODULATION

3.3.1 Laser: The Perkin-Elmer Model 5800 Laser, used as the light source, is a single coherent wavelength (6328Å) laser with an output power of 0.25 milliwatt. The specifications are given in Table I.

3.3.2 Image Dissector: The ITT F5005 image dissector has a 1.10-inch aperture and is linear over 80 percent of its diameter. It uses a 0.0015-inch scanning aperture with an S-20 photocathode surface and thus has high sensitivity at 6328Å. (Further details concerning this unit are available in the ITT Vidisector Operation Manual.)

3.3.3 Doppler Frequency Modulator: Modulation of the laser output frequency to achieve phase modulation is accomplished by controlling the piezoelectric element located in the Doppler frequency shifter. A triangular wave

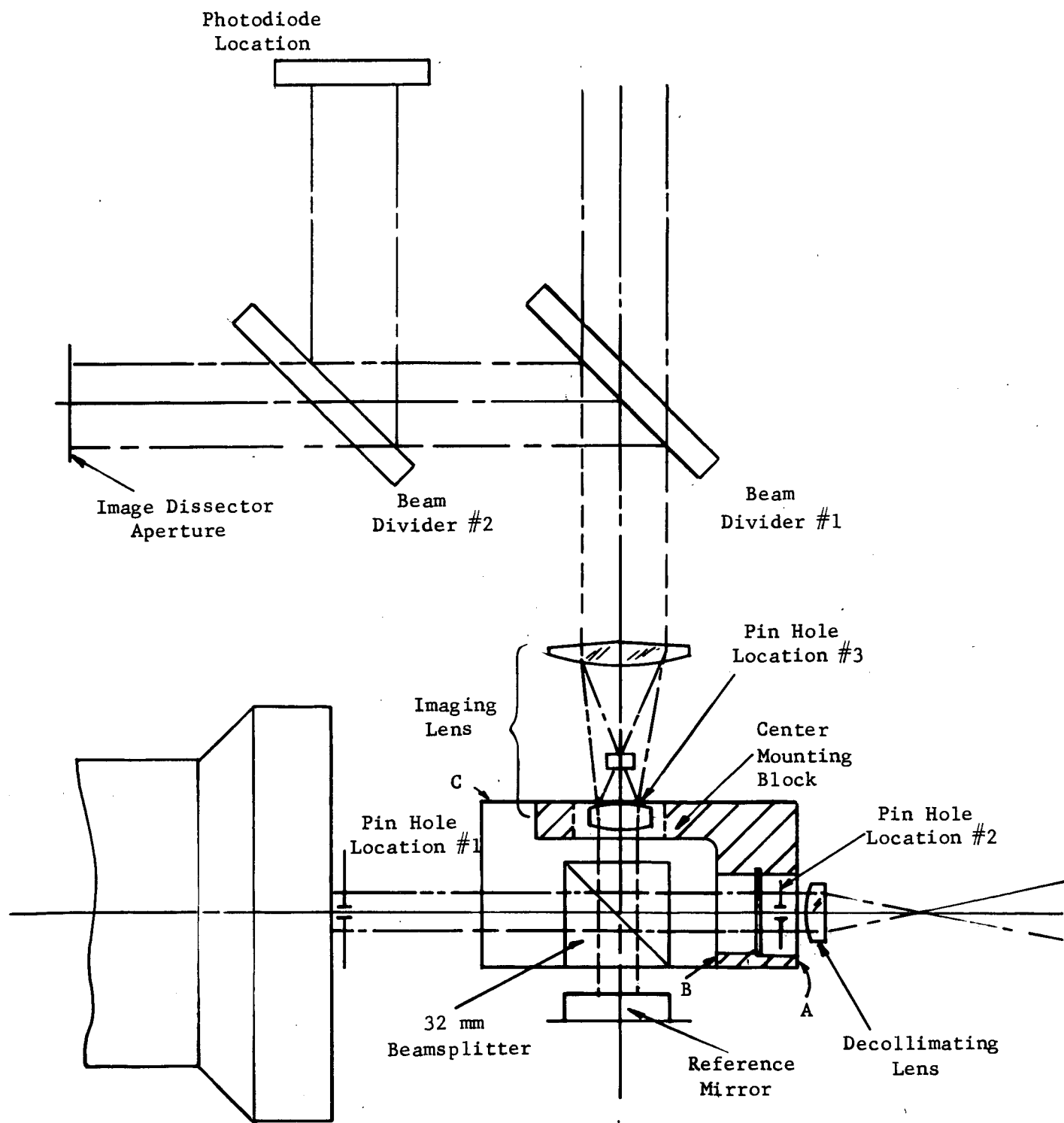


Figure 9. Figure Sensor Optical Layout

TABLE I
LASER SPECIFICATIONS

| | |
|---------------------|-------------------------------------|
| Model No: | 5800, Perkin-Elmer |
| Output Wavelengths: | 6328 ⁰ A |
| Output Power: | 0.25 mw, uniphase, single frequency |
| Beam Diameter: | 1mm, 1 percent intensity points |
| Beam Divergence: | 2.5 mrad |
| Input Power: | 50/60 Hz; 115/230V, 100VA max. |
| Warm-up Time: | 2-1/2 Hrs. Max. from off condition |
| Power Supply: | Model 5801 |

generator and amplifier is used to drive the piezoelectric element. The operating sweep frequency is 18 Hz. The equivalent optical range between the test mirror arm and the reference mirror arm is five to six wavelengths. The resulting carrier frequency, as seen at the output of the photodiodes or image dissector, is 185 Hz.

3.4 MANUAL ADJUSTMENT STAND

The figure sensor assembly is mounted to a five degree of freedom manual adjustment stand. Three motions are translational (x,y, and z), and two motions are angular (cross the line of sight). The stand is designed so that every adjustment is along or relative to the optical axis defined by the decollimating lens focal point (Point F, Figure 5). Precision bearings are used throughout the adjustment stand with preload springs in every adjustment axis to eliminate backlash and enhance repeatability. The specifications for the stand are given in Table II.

Locking screws (four total) are provided to lock the figure sensor (main external frame) to the manual adjustment stand main mounting base once the figure sensor adjustments have been made.

3.5 SIGNAL PROCESSING ELECTRONICS

The figure sensor signal processing electronics, shown in the system block diagram of Figure 5, include the thermal compensating mount closed-loop electronics, image dissector output error and scanning electronics, laser frequency modulation electronics, power supplies, and console instrumentation.

3.5.1 Thermal Compensating Mount Closed-Loop Electronics: The tilt angle signals used eventually to command the thermal compensator actuators are derived by a pair of photodiodes located in the interferometer fringe pattern. The diodes are situated in the fringe pattern at a moment arm about the tilt axis of the test mirror as imaged at the fringe pattern. Three diodes

TABLE II
ADJUSTMENT STAND SPECIFICATIONS

| | |
|------------------|---|
| Travel: | $\pm 1/4$ degree, two angular axes |
| | $\pm 1/4$ inch, x and y axes |
| | $\pm 1/2$ inch, focus |
| Load Capability: | 200 pounds |
| Resolution: | ± 0.001 inch, x,y, and z axes |
| | ± 20 arc-seconds, each angular axis |

are required for two tilt axes including one common (reference) diode, as illustrated in Figure 5. The photodiodes sense the test mirror tilt angle by measuring the optical phase shift that occurs across the mirror when it is angularly misaligned with respect to the spherical reference mirror. These optical phase shifts are converted into DC output voltages by 90-degree phase detector circuits and fed to the thermal compensator drive amplifiers. An optical path difference of $1/8\lambda$ equals $1/4$ fringe, which is identical to an electrical phase shift of 90 degrees.

A "threshold" feature is used to automatically turn off the actuators in both axes whenever the mirror tilt errors have been nulled. This technique voids limit cycling. The thermal compensator actuators servo loop is a "bang-bang" type of controller and, unless disabled, will oscillate or limit cycle at a high frequency about the zero error point. As the mirror tilt errors increase above selected threshold levels, the actuator servo loop automatically becomes active to again nullify these errors.

Because of the ambiguous output signal of the phase detector circuits whenever errors exceed $\pm 1/4\lambda$ or $\pm 1/2$ fringe⁽²⁾, coarse alignment is incorporated to initially place the diodes within the correct (uniphase) operating range. This is accomplished by using the image dissector. The image dissector signals are fed into the thermal compensators while the dissector aperture is allowed to scan slowly from the projected reference diode point on the mirror to the adjacent diode point on the mirror in a given axis. As the image dissector scans, the thermal compensator actuators correct the tilt error at a rate proportional to the accumulated error across the mirror.

The controls for the two thermal/compensator actuators are located on the front panel of the control console as shown in Figure 10. Provisions have been made for selecting fine and coarse alignment, left and right slewing commands, and turning the actuators off.

(2) The phase detector output signals repeat every one fringe or $1/2$ wavelength.

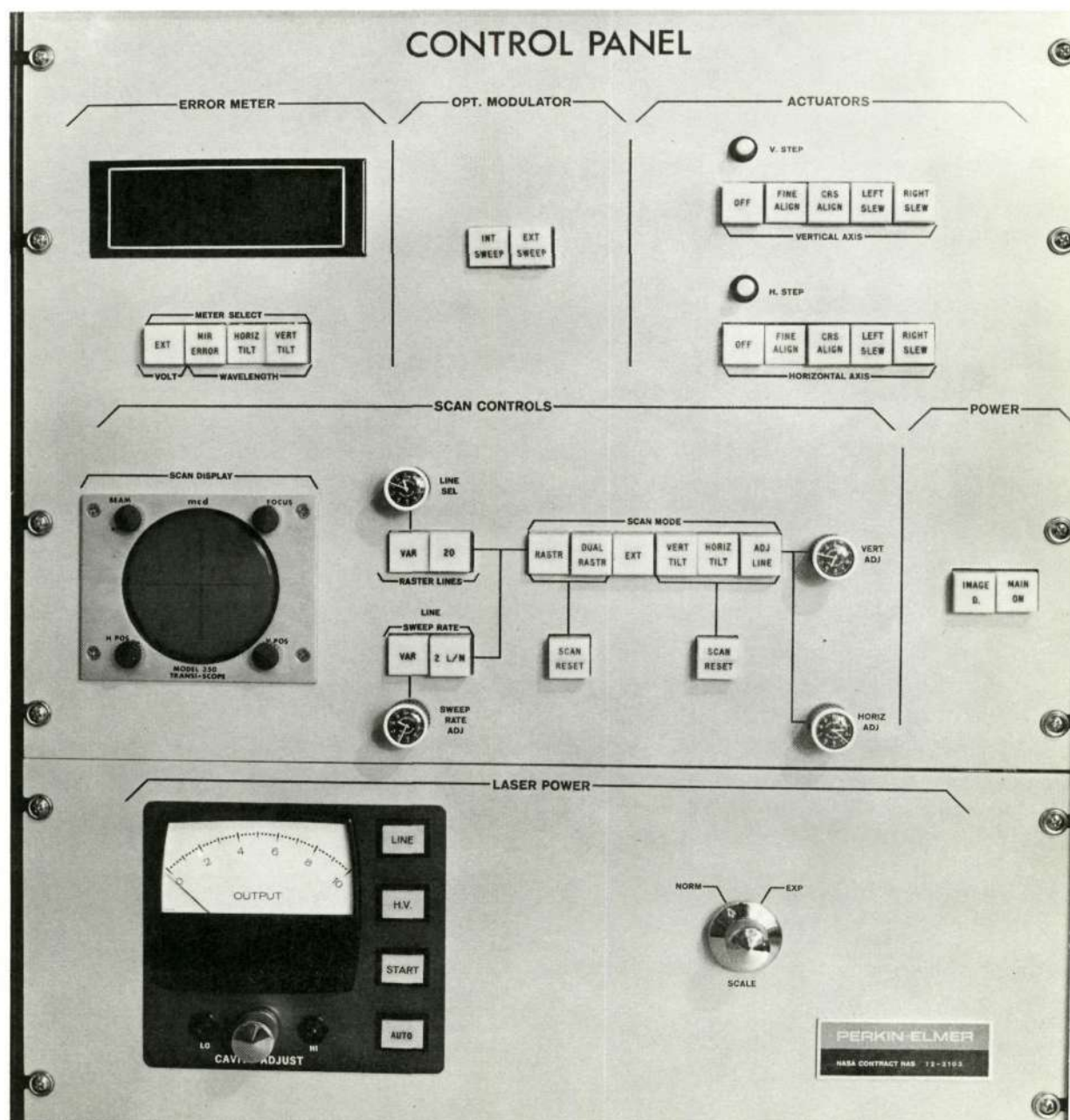


Figure 10. Figure Sensor Control Panel

3.5.2 Image Dissector Output Error and Scanning Electronics: The image dissector can measure the figure error of the test mirror, at any point, by scanning with a small 0.0015-inch aperture. The dissector output signals are compared with the reference photodiode to determine the optical phase shifts proportional to figure error. These shifts are converted into DC output voltages by phase detector circuits such as those used for the photodiodes.

Several scanning modes are used with the image dissector. The basic mode for measuring the error over the complete surface of the test mirror is a raster scan. During a raster scan the image dissector 0.0015-inch aperture sweeps horizontally across the fringe pattern (left to right), drops vertically by a small increment, and again sweeps horizontally across the fringe pattern (right to left); it continues this process until the entire fringe pattern has been scanned. Digital/analog circuits are used to generate the raster scans. A digital "staircase" type generator drives the deflection coils of the image dissector to accomplish vertical incremental steps and an analog triangular wave generator drives the deflection coils to achieve the horizontal sweeps. The raster scan circuits have both a fixed line spacing (20) and fixed sweep rate (two lines/one minute) control as well as a variable line spacing and sweep rate control. The raster scan controls are located on the console front panel (see Figure 9, Section 4.0). A "dual line" raster scan feature is also included to enable the image dissector aperture to automatically retrace each line for repeatability measurements.

Single line horizontal and vertical sweeps are used for coarse alignment of the thermal compensating mount, i.e., to achieve a uniphase fringe pattern. An analog sweep generator is used for this purpose and utilizes an operational integrating amplifier. This same analog scanning generator is used to equip the figure sensor electronics with an "adjustable line" scan feature. The adjustable line switch (Figure 10) allows an operator to set the image dissector scanning aperture to any point on the aperture of the test mirror where it will dwell as long as desired. An automatic single line scan can also be initiated to sweep from the reference diode to the selected point.

Finally, provisions have been made to bring in external scanning signals to the console via a test box (Figure 11), which feeds into a rear connector (J8) on the console. A front panel switch has been provided for this purpose in the bank of scan mode select switches.

3.5.3 Doppler Frequency Modulation Electronics: An analog triangular wave generator is used to derive the triangular waves that are fed to the high voltage piezoelectric drive amplifier. The solid-state transistorized amplifier is capable of producing output voltages up to 1200 Vdc at frequencies of one KHz, or greater, that operate into capacitive type piezoelectric loads. This high voltage amplifier drives the piezoelectric elements in the Doppler frequency shifter at an 18 Hz frequency over 10 to 18 fringes, which result in a nominal carrier frequency of 185 Hz.

Front panel switches located on the console initiate Doppler frequency modulation (INT. SWEEP). Provisions also are available to select external sweeps (EXT. SWEEP) fed from other types of generators.

3.5.4 Power Supplies: The figure sensor power system is completely self-contained and requires only 115 VAC, 50/60 Hz input power. All DC power supplies are solid-state, modularly constructed, regulated, and consist of the component parts listed in Table III.

All power supplies are located in the control console. The controls for the laser power supply are located on the console front panel. The image dissector power unit is controlled by a single front panel switch. Similarly, all the DC power supplies are turned on by a single front panel switch which actuates several relays to supply 115 VAC, 60 Hz to all power units.

3.6 INSTRUMENTATION

In addition to the front panel switches that control power, scanning modes; thermal compensator actuators, and the optical modulator, a

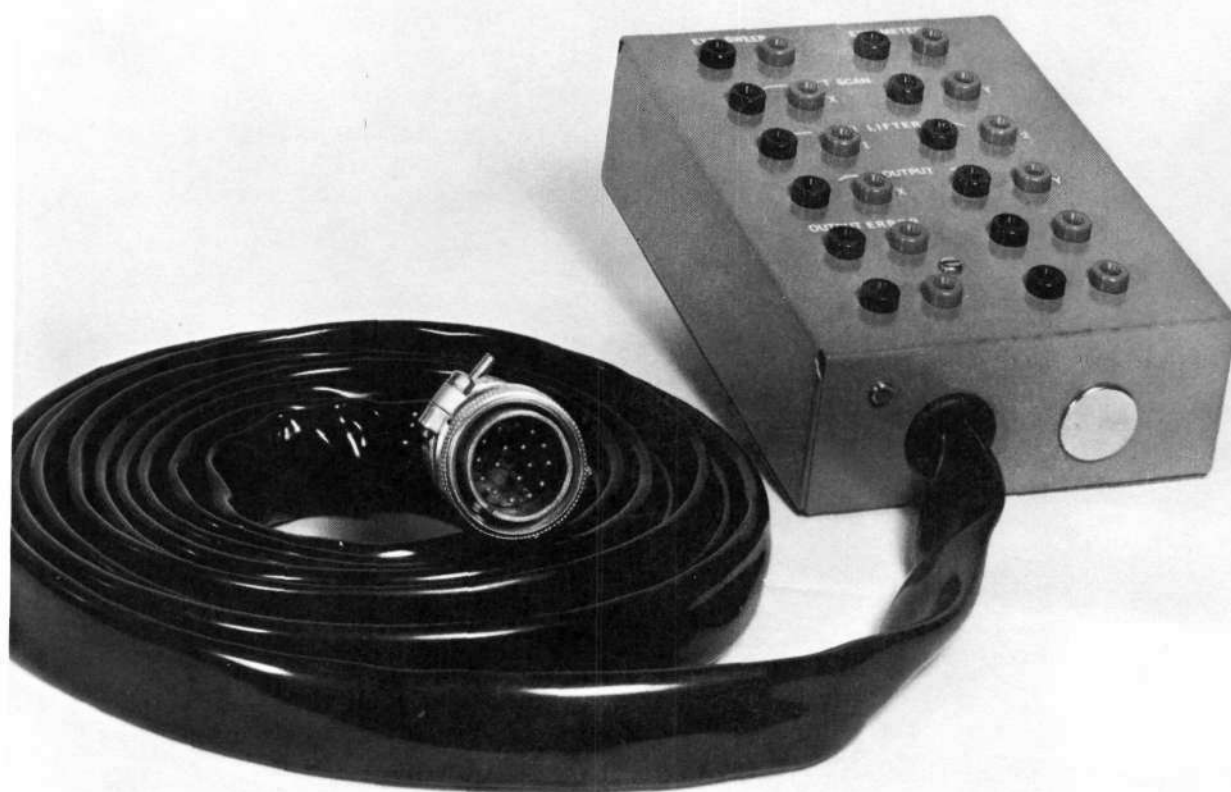


Figure 11. Test Box

TABLE III
POWER SUPPLY UNITS

| <u>Unit</u> | <u>Application</u> |
|-------------|---|
| +15 Vdc | Operational Amplifiers |
| -15 Vdc | Operational Amplifiers |
| +12 Vdc | Digital Circuits |
| -6 Vdc | Digital Circuits |
| +5 Vdc | Digital Circuits |
| +28 Vdc | Relay Voltages |
| +1380 Vdc | Doppler Frequency Modulation Amplifier |
| +400 Vdc | Peristaltic Actuator Amplifiers |
| +28 Vdc | Stepper Motor |

3-1/2 digit digital error meter and a three inch oscilloscope are incorporated into the figure sensor electronics. The digital error meter can be selected to read the mirror figure error (i.e., output of the image dissector phase detector circuits); the photodiode vertical and horizontal phase detector output signals; the external voltages fed through the console test box; and the thermal compensation actuator positions. The three inch oscilloscope is permanently connected to monitor the signals going to the vertical and horizontal deflection coils of the image dissector. The oscilloscope therefore visually displays the scan modes.

During each raster scan, an automatic timer resets the image dissector output to zero. The reset feature permanently records the point of zero error.

A pen lifter circuit is used to lift the x-y 7000 Hewlett Packard recorder pen whenever the image dissector scan is off the mirror surface.

3.7 ADDITIONAL FEATURES

The figure sensor assembly and console are designed to allow major components to be removed easily. The ITT F5005 image dissector camera and control unit can each be removed from the figure sensor and console and separately operated. The interconnecting cable (J10, J9) between the console and figure sensor assembly can be connected directly to the image dissector camera and control unit. Similarly, the Model 5800 Perkin-Elmer Laser and 5801 power supply also can be removed and operated separately.

An external test box, 8x8x2 inches, with mounted test jacks is provided (Figure 11). External inputs for the error meter, optical modulator and the scan controls can be fed to the electronics via this test box. The box also contains the mirror figure error outputs from the image dissector circuits and the recorder pen lifter signals.

4.0 OPERATIONS PROCEDURE

4.1 CONTROLS AND INDICATORS

All the controls and indicators required, for operating the figure sensor are located on the console front panel (see Figure 10). The function of each control and indicator is listed below. The console front panel nomenclatures are given in capital letters.

4.1.1 Power Indicators and Controls:

| | |
|---------|--|
| IMAGE D | An alternate action pushbutton switch that turns the 115 VAC, 60 Hz line power for the ITT F5005 image dissector on or off. The pushbutton lights to indicate power is on. |
| MAIN ON | An alternate action pushbutton switch that turns the DC power supplies, digital error meter, and Model 350 Transiscope on. The pushbutton lights to indicate power is on. |

4.1.2 LASER POWER Indicators and Controls

| | |
|-------|--|
| LINE | An alternate action push-to-make, push-to break switch that turns the line power for the laser on or off. The pushbutton lights to indicate power is on. |
| HV | An alternate action pushbutton switch that makes high voltage available for the laser. The pushbutton lights to indicate high voltage section is armed. |
| START | A momentary type pushbutton switch that starts laser when depressed. Switch has no effect until button lights (indicating that high voltage is on) 30 to 40 seconds after the LINE switch and the HV switch in the on conditions. |
| AUTO | A pushbutton switch to change mode of operation from manual to automatic. The button lights to indicate the laser is operating in the automatic (closed loop) mode. The switch is inoperative in this unit which is not equipped with the closed loop circuit cards. |

| | |
|---------------|--|
| CAVITY ADJUST | A control (potentiometer) that provides manual adjust of the cavity length of the laser. The full range of this adjustment covers approximately 2-1/2 to 3 orders. The CAVITY ADJUST control is inactive during the automatic mode of operation. |
| HI and LO | Pilot lights that indicate the upper (HI) and lower (LO) limits of the cavity length adjustment range have been reached. When either indicator light is on, a manual readjustment of the CAVITY ADJUST control is required. |
| OUTPUT | Meter which gives relative indication of laser output power with SCALE switch in the NORM (normal) position. Also aids in locating the peak-power points and Lamb dip with the cavity length is adjusted manually. |
| SCALE | A two-position switch used to change the sensitivity of the OUTPUT meter; contains an inner knob to zero-suppress the expanded scale. With the switch in the NORM position the meter indicates relative power output with respect to zero. The NORM position is used to locate maximum power points. The EXP (expanded) position is used during fine adjustment of the CAVITY ADJUST control, for precise location of the Lamb dip. The EXP scale may be shifter up or down, as required, by the inner knob, which provides a zero-suppression adjustment. |

4.1.3 OPT. MODULATOR Controls and Indicators

| | |
|-----------|--|
| INT SWEEP | An alternate action pushbutton switch that activates the Doppler frequency shifter modulator drive amplifier. When this switch is ON, the piezoelectric crystal is driven with triangular wave input at 18 Hz to provide phase modulation in the figure sensor interferometer. The pushbutton lights to indicate the internal phase modulator is active. |
| EXT SWEEP | An alternate action pushbutton switch the provides external sweep signals to the Doppler frequency modulator drive amplifier. External signals can be fed to the piezoelectric crystal through the console test box (EXT SWEEP) when this switch is activated. The pushbutton lights to indicate external sweep signals are being used. |

4.1.4 ACTUATOR Controls and Indicators

Vertical Axis:

- | | |
|------------|--|
| OFF | A bailing pushbutton switch that disconnects all input signals going to the vertical thermal compensator actuator drive amplifier. The vertical axis of the thermal mount is in a holding status when this switch is activated. The pushbutton lights to indicate the OFF status. |
| FINE ALIGN | A bailing pushbutton switch that places the vertical axis of the thermal control mount in the FINE ALIGNment closed loop mode. The thermal mount will automatically correct for angular tilt of the test mirror within a <u>single</u> fringe in this mode. The pushbutton lights to indicate closed loop photodiode operation. |
| CRS ALIGN | A bailing pushbutton switch that places the vertical axis of the thermal control mount in the CoarSe (CRS) ALIGNment closed loop mode. CoarSe ALIGNment, i.e., alignment of the tilt axis to <u>within</u> a single fringe, can be accomplished in this mode. The pushbutton lights to indicate image dissector closed loop operation. |
| LEFT SLEW | A bailing pushbutton switch that commands the vertical actuator to SLEW LEFT at a constant rate. The pushbutton lights to indicate the slewing mode. |
| RIGHT SLEW | A bailing pushbutton switch that commands the vertical actuator to SLEW RIGHT at a constant rate. The pushbutton lights to indicate the slewing mode. |
| V. STEP | An indicator that fires at the beginning of each correcting sequence being fed to the vertical thermal compensator actuator. |

Horizontal Axis:

- | | |
|-----|---|
| OFF | A bailing pushbutton switch that disconnects all input signals going to the horizontal thermal compensator actuator drive amplifier. The horizontal axis of the thermal mount is in a holding status with this switch is activated. The pushbutton lights to indicate the OFF status. |
|-----|---|

| | |
|------------|---|
| FINE ALIGN | A bailing pushbutton switch that places the horizontal axis of the thermal control mount in the FINE ALIGNment closed loop mode. The thermal mount will automatically correct for angular tilt of the test mirror within a <u>single</u> fringe in this mode. The pushbutton lights to indicate closed loop photodiode operation. |
| CRS ALIGN | A bailing pushbutton switch that places the horizontal axis of the thermal control mount in the Coarse (CRS) ALIGNment closed loop mode. Coarse ALIGNment, i.e., alignment of the tilt axis to <u>within a single fringe</u> , can be accomplished in this mode. The pushbutton lights to indicate image dissector closed loop operation. |
| LEFT SLEW | A bailing pushbutton switch that commands the vertical actuator to SLEW LEFT at a constant rate. The pushbutton lights to indicate the slewing mode. |
| RIGHT SLEW | A bailing pushbutton switch that commands the vertical actuator to SLEW RIGHT at a constant rate. The pushbutton lights to indicate the slewing mode. |
| H. STEP | An indicator that fires at the beginning of each correcting sequence being fed to the horizontal thermal compensator actuator. |

4.1.5 SCAN MODE Controls and Indicators:

| | |
|------------|--|
| RASTR | A bailing pushbutton switch that places the image dissector in a raster scanning select mode. During a raster scan, the small (0.0015 inch) image dissector aperture sweeps horizontally across the fringe pattern, drops vertically downward by a small increment, again sweeps horizontally back across the fringe pattern, and continuing this process until the entire fringe pattern has been scanned. The pushbutton lights to indicate the RASTR scan mode is selected. |
| DUAL RASTR | A bailing pushbutton switch that places the image dissector in a repeating raster scan select mode. The function of this switch is identical to the RASTR mode except that each horizontal sweep is repeated before dropping vertically downward to the next line. The pushbutton lights to indicate the DUAL RASTR scan mode is selected. |

| | |
|------------------------------|---|
| SCAN/RESET (left switch) | An alternate action pushbutton switch that activates either the RASTR or DUAL RASTR scan mode. The pushbutton lights to indicate the SCAN mode is on. RESET indicates the scan mode is off. |
| EXT. | A bailing pushbutton switch that selects external scan signals from the console test box (EXT SCAN). The pushbutton lights to indicate the EXTERNAL scan mode is selected. |
| VERT TILT | A bailing pushbutton switch that places the image dissector in a VERTICAL scan select mode. A vertical scan consists of a single line sweep in the vertical direction. This type of scan is used for coarse alignment of the thermal mount. The pushbutton lights to indicate the VERT TILT mode is selected. |
| HORIZ TILT | A bailing pushbutton switch that places the image dissector in a HORIZONTAL scan select mode. A horizontal scan consists of a single line sweep in the horizontal direction. This type of scan is used for coarse alignment of the thermal mount. The pushbutton lights to indicate the HORIZ TILT mode is selected. |
| ADJ LINE | A bailing pushbutton switch that places the image dissector in an adjustable, single line, scan select mode. This type of scan is used to measure errors at any point on the mirror surface with respect to the reference diode. The VERT ADJ and HORIZ ADJ potentiometer determine the location of the selected point. The pushbutton lights to indicate the ADJ LINE is selected. |
| SCAN/RESET (right switch) | An alternate action pushbutton switch that activates either the VERT TILT, HORIZ TILT, or the ADJ LINE scan modes. |
| VERT ADJ | A potentiometer that sets the vertical point on the mirror. This control is used during the ADJ LINE scan mode. |
| HORIZ ADJ | A potentiometer that sets the horizontal point on the mirror. This control is used during the ADJ LINE scan mode. |

4.1.6 RASTER LINES Controls and Indicators

| | |
|----------|--|
| VAR | An alternate action switch that is used to select any number of raster lines for the RASTR and DUAL RASTR scan modes. The LINE SET potentiometer is used in this mode. The pushbutton lights to indicate the VARIABLE line mode is selected. |
| 20 | An alternate action switch that is used to select a fixed (20) number of raster lines for the RASTR and DUAL RASTR scan modes. The pushbutton lights to indicate the fixed 20 line mode is selected. |
| LINE SEL | A potentiometer control used to select the number of raster lines when using the VARIABLE raster line select mode. |

4.1.7 LINE SWEEP RATE Controls and Indicators

| | |
|----------------|--|
| VAR | An alternate action switch that is used to set the raster sweep rate for the RASTR and DUAL RASTR scan modes. The SWEEP RATE ADJ potentiometer is used in this mode. The pushbutton lights to indicate the VARIABLE mode is elected. |
| 2L/M | An alternate action switch that is used to select a fixed (two lines per minute) sweep rate for the RASTR and DUAL RASTR scan modes. The pushbutton lights to indicate the fixed 2L/M is selected. |
| SWEEP RATE ADJ | A potentiometer control used to select the sweep rate when using the VARIABLE line sweep rate select mode. |
| SCAN DISPLAY | An oscilloscope which displays the type of scan mode being used. The scope monitors the signals being supplied to the x and y axes image dissector deflection coils. |

4.1.8 ERROR METER Controls and Indicators

| | |
|-----|---|
| EXT | A bailing pushbutton switch that selects and displays external voltages on the meter. External voltages are fed through the console test box (EXT METER). The digital voltmeter reads voltage directly in this mode. The position of the thermal compensation actuators can also be monitored in this mode. A three position toggle switch has been mounted at the rear of the chassis just under the printed circuit board rack (Figure 12). When the error meter is |
|-----|---|

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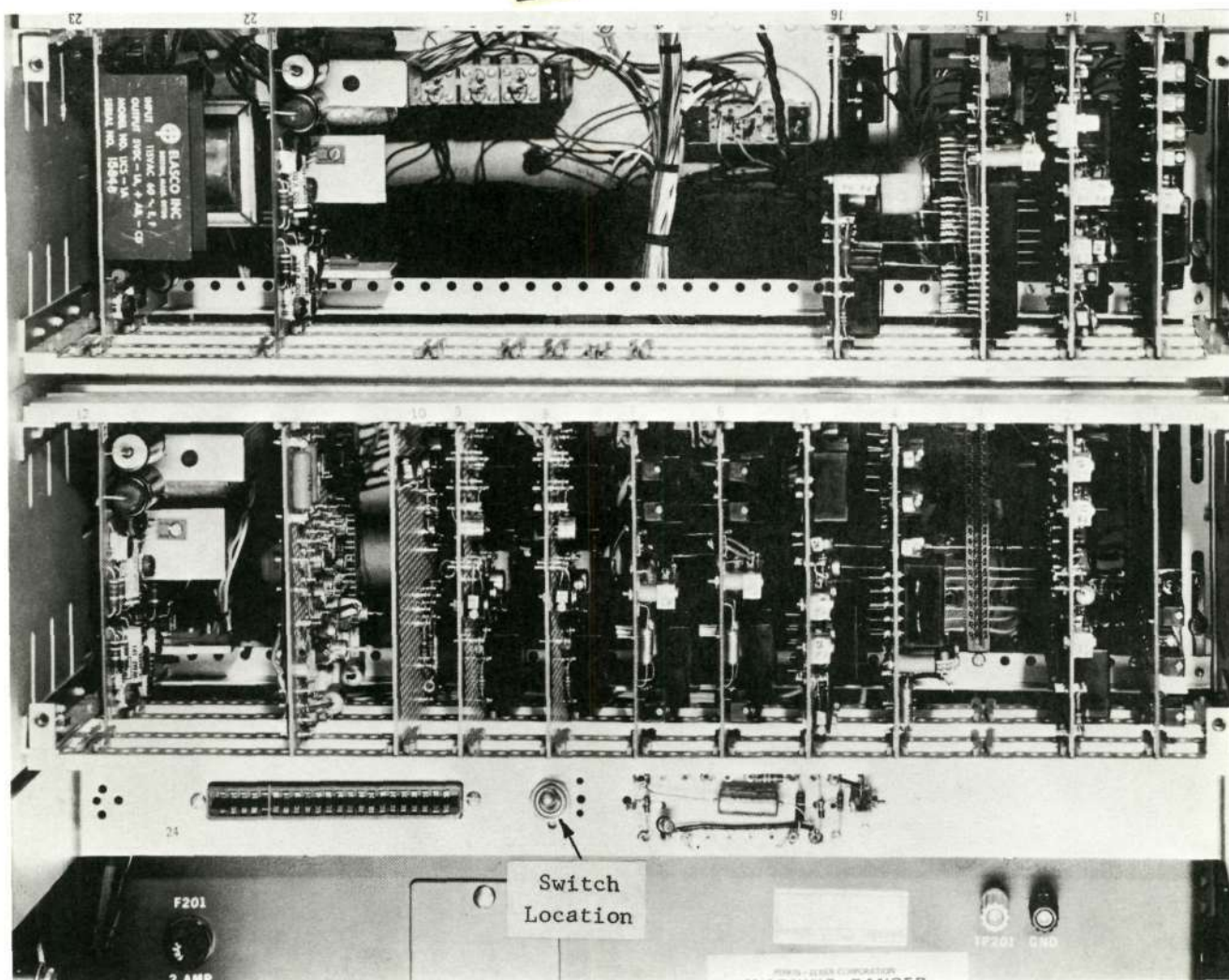


Figure 12. Thermal Actuator Monitor Selector Switch

in the EXT mode, the horizontal actuator position, the external voltages, and the vertical actuator position are displayed corresponding to toggle switch positions of up, center, or down, respectively. The range of each actuator as indicated on the meter is from 0 to 1.000 volt with 0.500 volt being the mid-range position.

MIR ERROR

A bailing pushbutton switch that selects and displays test MIRROR Figure ERROR. The digital voltmeter monitors the output of the image dissector

phase detector circuit in this mode and is scaled to read error in wavelengths.

HORIZ TILT A bailing pushbutton switch that selects and displays the thermal mount horizontal tilt error. The digital voltmeter monitors the output of the horizontal photodiode phase detector circuit in this mode and is scaled to read error in wavelengths.

VERT TILT A bailing pushbutton switch that selects and displays the thermal mount vertical tilt error. The digital voltmeter monitors the output of the vertical photodiode phase detector circuit in this mode and is scaled to read error in wavelengths.

4.2 OPERATION PROCEDURES

Prior to operating the figure sensor, make sure all electrical connections have been made as listed in Section 2.3, and that the system has been optically alined as described in Section 5.2.

4.2.1 Laser Power On Procedure:

1. Press the LINE switch. The indicator lamp should light and the filament in the laser tube should be energized within 15 seconds.

2. Press the HV pushbutton switch. The HV button should light immediately. The START switch should light about 30 seconds after the LINE and HV switches have been pressed.

3. Make sure that the AUTO switch is in the manual position (that the AUTO button is not lit).

4. After the START pushbutton lights, press the START switch momentarily to turn the laser on.

5. Turn the SCALE switch to the NORM position and slowly turn the CAVITY ADJUST control for maximum power indication on the OUTPUT meter. Neither the HI nor LO pilot light should be lit; if one is lit, find a new peak by re-adjusting the CAVITY ADJUST control.

NOTE: The laser is operational at this point. However, during the warm-up period (two and a half hours), the power output and frequency will change until the preset operating temperature is achieved and stabilized. If the power and/or the frequency stability of the laser is the primary requirement, then a waiting period of two hours between steps 1 (pressing the LINE switch) and 2 (pressing the HV switch) is recommended. An additional 1/2 hour waiting period after the laser is started, as described in step 4, is also recommended.

6. Set the SCALE selector to the EXP position and, with the inner knob of the SCALE switch, set the pointer of the OUTPUT meter between 8 and 10 with the CAVITY ADJUST control set for maximum power.

7. Slowly turn the CAVITY ADJUST control either clockwise or counterclockwise until a Lamb dip is detected on the meter. The Lamb dip is two to four major division deep between two peak readings.

8. When a Lamb dip is observed press the AUTO pushbutton. The pointer of the OUTPUT meter should remain stationary if the laser is "locked in", and any further manual adjustment of the CAVITY ADJUST control will be ineffective.

9. To turn off the laser beam but leave the power supply in a standby condition: (a) press the HV switch and (b) turn the AUTO switch off (AUTO button not lit). To re-ignite the laser, perform steps 2 and 4 above. The laser will stabilize within 30 minutes.

10. To turn off the laser, press both the LINE and HV pushbutton switches.

4.2.3 Console Power On Procedure

1. Power is fed to the console and auxiliary equipment through a convenience 115 Vac, 60 Hz outlet strip. Turn on master switch (on other strip).

2. Turn Scan Oscilloscope Display on (upper left knob). It may be necessary to increase the oscilloscope BEAM intensity and adjust beam FOCUS for better viewing. The H POS and V POS oscilloscope adjustments can also be checked for correct setting using the zero voltage position (with MAIN ON in off position) as reference. The oscilloscope beam should be located in the center position of the screen.

NOTE: Also check to verify that all the four switches (5 Vdc, 1500 Vdc, 400 Vdc, 28 Vdc) located on the power supply test panel are on and the 115 Vac, 60 Hz bus bar circuit breaker is on (Figure 13, Section 5.2).

3. Press the MAIN ON switch. The pushbutton lamp should light indicating all the DC power supplies are on and the ERROR METER is on.

4. Press the IMAGE D. switch. The pushbutton lamp should light indicating the 115 Vac, 60 Hz is applied to the Image Dissector camera and control unit.

4.2.3 Coarse and Fine Alignment Procedures

Prior to the optical alignment it is recommended that the actuators be positioned in the middle point of their total travel. This is achieved by slowing the actuator in one direction until they reach the end position, then slewing them in the opposite direction for 35 seconds (70 seconds is the total slewing time).

Coarse alignment of the figure sensor is required in order to reduce the vertical and horizontal tilt errors to within $\pm 1/4$ wavelength or $\pm 1/2$ fringe. This procedure assures that the figure sensor is aligned within $1/4$ fringe with respect to the test mirror and also within the fine alignment operating range of the thermal mount. The laser and console power on procedures and the manual alignment of the figure sensor within one or two fringes are required prior to final alignment.

Vertical Axis:

1. Press the VERT TILT error meter switch.
2. Press the VERT TILT scan mode switch. The SCAN/RESET switch (left) should be off or in the RESET position. The SCAN DISPLAY oscilloscope beam should be in the lower right-hand corner.
3. Press the VERTICAL axis actuator CRS ALIGN switch. This closes the thermal mount control loop. Vertical tilt errors, as displayed on the ERROR METER, should be 0.250λ or less when the thermal mount servo loop is nulled. The STEP indicator will stop flashing when the servo loop is a null.
4. Initiate the VERT TILT scan mode by pressing the SCAN/RESET switch (left). The SCAN DISPLAY oscilloscope beam should trace from right to left (looking at the front of the panel) at a slow rate (approximately one to two minutes).
5. Observe the ERROR METER horizontal tilt error. During a single sweep of the horizontal tilt scan, the errors should not exceed $\pm 0.250\lambda$. If the errors are greater than 0.250λ , repeat step 4 above by resetting and again initiating the VERT TILT scan mode.
6. RESET the VERT TILT scan mode.
7. Press the FINE ALIGN switch for the vertical actuator.
8. Observe the vertical tilt error on the ERROR METER. The error should reduce to a minimum level corresponding to the actuator threshold setting used in the fine alignment closed loop mode. The threshold level error is normally 0.02λ or less.

Horizontal Axis:

1. Press the HORIZ TILT error meter switch.

Horizontal Axis

2. Press the HORIZ TILT error meter switch.
3. Press the HORIZ TILT scan mode switch. The SCAN/RESET switch (left) should be off or in the RESET position. The SCAN DISPLAY oscilloscope beam should be in the lower right-hand corner.
4. Press the horizontal axis actuator CRS ALIGN switch. This closes the thermal mount control loop. Horizontal tilt errors, as displayed on the ERROR METER, should be ± 0.250 or less when the thermal mount servo loop is nulled. The H. STEP indicator will stop flashing when the servo loop is a null.
5. Initiate the HORIZ TILT scan mode by pressing the SCAN/RESET switch (left). The SCAN DISPLAY oscilloscope beam should trace right to left at a slow rate (approximately 1 to 2 minutes).
6. Observe the ERROR METER horizontal tilt error. During a single sweep of the horizontal tilt scan, the errors should not exceed ± 0.250 . If the errors are greater than $\pm 0.250\lambda$, repeat step 15 above by resetting and again initiating the HORIZ TILT scan mode.
7. RESET the HORIZ TILT scan mode.
8. Press the FINE ALIGN switch for the horizontal actuator.
9. Observe the horizontal tilt error on the ERROR METER. The error should reduce to minimum levels corresponding to the actuator threshold setting used in the fine alignment closed loop mode. The threshold level error is normally 0.02λ or less.

4.2.4 Calibration Check (Optional)

Calibration of the figure sensor, image dissector voltage output versus wavelength, can be checked by using the thermal mount to create tilt

errors. (Refer to section 3.5.) A tilt error of one fringe is equal to $1/2\lambda$. An error of one fringe will cause the image dissector and photodiode phase detector circuit outputs to go through a complete cycle. Calibration can be determined by measuring the slope of the voltage output through crossover (zero error). The Coarse and Fine Alignment Procedures should be carried out prior to the calibration check.

1. Monitor the MIR ERROR output at the console test box (OUTPUT, Y) with a chart recorder such as a 7000 x-y Hewlett Packard or Samborn two-channel recorder. If using an x-y recorder, place the x axis in an internal time sweep mode.

NOTE: - A bias voltage will also appear at the Y terminal OUTPUT of the test box corresponding in magnitude to the scan position.

2. Disengage the vertical and horizontal actuators by pressing the OFF switches.
3. Select the VERT TILT scan mode, press the SCAN/RESET (right) and leave the image dissector scanning aperture in the final vertical scan position.
4. Slew the vertical actuator by pressing the LEFT (or RIGHT) SLEW switch. Simultaneously record the MIR ERROR output on a chart recorder. Two to three cycles (or fringes) should be adequate for measurements.
5. Determine the calibration voltage output versus wavelength scale factor using the slope of the voltage output through crossover.
6. Return the vertical actuator to its original position by reversing the slewing direction and cycling back through the same number of fringes. Disengage the vertical actuator. RESET the scan mode.

7. Select the HORIZ TILT scan mode, press the SCAN/RESET (right), and leave the image dissector scanning aperture in the final horizontal scan position.
8. Slew the horizontal actuator by pressing the LEFT (or RIGHT) SLEW switch. Simultaneously record the MIR ERROR output on a chart recorder.
9. Determine the calibration scale factor (step 5 above).
10. Return the horizontal actuator to its original position. RESET the scan mode (step 6 above).

4.2.5 Raster Scan Readout Procedures

Test mirror figure errors can be recorded using the following procedures (the Coarse and Fine Alignment Procedure should be conducted prior to data readout).

1. Select the RASTR (or DUAL RASTR) scan mode.
2. Select the number of raster lines. Use either the 20 (fixed) or the VAR switch (and LINE SEL potentiometer) to set the desired number of raster lines. The number of raster lines selected can be determined using the SCAN DISPLAY oscilloscope.
3. Select the line sweep rate. Use either the 2L/M (fixed) switch or the VAR (and SWEEP RATE ADJ potentiometer) switch to select the desired sweep rate.
4. Monitor the mirror error output with a Hewlett Packard 7000A x-y recorder (or equivalent). This is accomplished by connecting the x-axis of the recorder to the OUTPUT -X jack on the test box; connecting the y-axis of the recorder to the OUTPUT -Y jack on the test box; and connecting the recorder pen lifter leads to jacks no. 1 and no. 2 on the test box.

NOTE: - The x and y axis scanning voltages fed to the image dissector are also fed to the X and Y OUTPUT test box jacks. In addition, the Y-OUTPUT contains the mirror figure error signals which are superimposed on the y-axis scan signal.

5. Press the SCAN/RESET (left) switch. The x-y recorder trace should start top-center and scan left. The pen should automatically lift whenever the scanning aperture drops off the mirror surface. If the DUAL RASTR scan mode is used, the recorder will retrace beginning with the second line.

NOTE: - Trial runs may be necessary to arrive at the proper sensitivity and bias settings for the x-y recorder. The figure error calibration scale factor, volts/wavelength, can be obtained using the Calibration Check Procedure (paragraph 4.2.4).

4.2.6 Adjustable Line Readout Procedures

1. Select the ADJ LINE scan mode.
2. Press the SCAN/RESET switch and allow the scan to reach its final position.
3. Set the final scan position to the desired location by using the VERT ADJ and HORIZ ADJ potentiometer. The SCAN DISPLAY oscilloscope can be used to observe the scan location.
4. Monitor the mirror error output with the x-y recorder using the OUTPUT ERROR jacks on the test box. Use the recorder time sweep for the x-axis input.
5. Re-initiate the scan using the SCAN/RESET switch. The mirror error existing between the mirror reference point and selected point will be plotted by the recorder.

5.0 OPTICAL ALIGNMENT PROCEDURE

The procedure used to optically align the figure sensor is described in this section and involves a process of both assembling and aligning the figure sensor, component by component, until the final optical/mechanical configuration is achieved. The following components are involved:

- 5800 Laser and Beam Expander
- 32mm Beamsplitter Cube
- Decollimating Lens
- Flat Reference Mirror
- Imaging Lens and Beam Dividers
- Image Dissector and Photo Diodes
- X, Y, Z Manual Adjustment Stand
- Spherical Test Mirror

Prior to proceeding with the steps listed below, the thermal compensation mount is centered and secured in both axes. The test setups described in Section 3.0 are used during alignment.

All optical lenses, beamsplitters, and mirrors are completely removed from the figure sensor assembly prior to alignment.

A mounting block containing the 32mm beamsplitter cube and imaging lens is used as a main alignment reference. It has three reference surfaces, "A", "B", and "C" as shown in Figure 12. Surfaces "A" and "B" are machined parallel to each other and perpendicular to surface "C".

5.1 LASER ALIGNMENT

The procedure to align the laser and beam expander to the center mounting block is as follows:

(1) In an optical bench, recheck the laser collimation. Place a parallel plate in front of the laser beam at 45 degrees inclination. Place a screen to observe the fringes formed and then to minimize the number of fringes by rotating the front lens cell of the beam expander.

(2) Install the 5800 laser and 32mm beamsplitter mounting block less optics. Square the mounting block with the figure sensor base plate and temporarily secure the block.

(3) Center the 16mm laser beam on the lens mounting hole.

(4) Place a 1-inch optical flat against surface "B" on the mounting block, looking toward the laser.

(5) Install a 0.020-inch diameter pin hole, mounted in a "X" and "Y" positioner in the 16mm laser beam near the front surface of the laser beam expander.

(6) Adjust the laser to align the reflected 0.020-inch beam to fall on the pin hole. This squares the laser with reference surfaces "B" and "A".

(7) Verify by temporarily removing pin hole no. 1 that the laser beam is illuminating the clear aperture of the decollimating lens. Repeat 3, 4, 5, 6, and 7 if necessary.

(8) Secure the laser and remove the 1-inch test flat.

5.2 BEAMSPLITTER ALIGNMENT AND REFINEMENT OF THE OPTICAL AXIS

With the 0.020-inch pin hole located in front of the laser beam expander, the 32mm beamsplitter cube is aligned to the optical axis as follows:

(1) Install a 0.020-inch pin hole (nos. 2 and 3) in each of the threaded mounting holes of the center block.

(2) Adjust the pin hole, no. 1 "X" and "Y", cross slide until the 0.020-inch laser beam is centered in pin hole no. 2. This defines the optical center line.

(3) Install a one-inch test flat in the test arm of the interferometer (in front of surface "B"). Adjust so as to align the reflected beam to fall back on the pin hole no. 1 and 2.

(4) Install the 32mm beamsplitter on its titanium base and center on the mounting block. Align until the reflected beam from the one-inch flat is reflected and falls in both pin holes no. 1 and 3. The ghost reflection from the first surface of the beamsplitter encountered by the 0.020-inch laser beam also should fall in the pin hole no. 1.

5.3 RELAYING OPTICS, IMAGE DISSECTOR, REFERENCE MIRROR, and PHOTODIODE ALIGNMENT

Using the setup remaining in step 4 above with the three 0.020-inch pin holes locating the optical axis, the remaining optics are assembled as follows:

(1) Install the doppler frequency shifter. Center the reflected beam in the clear aperture of the imaging lens. Align until the reflected beam falls back in both pin holes (1 and 3).

(2) Install the two inch diameter beam divider #1 (see Figure 9). Center this flat on the 0.020 inch beam and adjust its angular position to deflect the laser beam at a right angle toward the image dissector.

(3) Install the photodiode holder and align beam divider #2 to center the photodiode cluster with the 0.020 inch laser beam. Align the image dissector to center its 1.10 inch aperture on the laser beam. This can be done by installing a forth pin hole on the threaded lens holder of the image dissector. Realign beam divider #1 if necessary.

(4) Verify by energizing the unit, setting the deflection coils at zero and refining its position until the 0.0015 inch diameter scanning aperture senses the 0.020 inch laser beam (i.e., monitor the signal output).

(5) Remove pin holes nos. 2 and 3 and install imaging lens.

5.4 ALIGNMENT OF THE DECOLLIMATING LENS AND TEST MIRROR

Install the decollimating lens and the test mirror. Align the test mirror, the figure sensor or both, until fringes are observed. Do not adjust the reference mirror. Further adjust for zero fringe. If the unit has been perfectly aligned, a secondary set of circular fringes will be observed. In

that condition the light is reflected back at its source, the laser, producing laser frequency instability. Readjust the reference mirror so as to focus the returning beam slightly off center to eliminate the secondary fringes. Readjust the test mirror to achieve uniphase in the primary interference pattern. At this point the real time figure sensor is fully operational. Proceed with the steps described in Section 4.2 OPERATION PROCEDURES.

6.0 ELECTRICAL CHECKS

TABLE IV

FUSES

| <u>Fuse No.</u> | <u>Volts</u> | <u>Function</u> |
|-----------------|--------------|--------------------|
| 1 | S1o-B1o 1 | -6V Power Supply |
| 2 | S1o-B1o 1 | 400V Power Supply |
| 3 | 250V 1 | 24V Power Supply |
| 4 | 250V 2 | 1500V Power Supply |
| 5 | 250V 1 | Transformer |
| 6 | 250V 3 | 15V Power Supply |
| 7 | 250V 1/4 | Digital Volt Meter |
| 8 | | Spare |

TABLE V

TEST POINTS

| <u>Top No.</u> | <u>Function</u> |
|----------------|-----------------|
| 1 | Y-Scan |
| 2 | X-Scan |
| 3 | Figure Error |
| 4 | Vertical Tilt |
| 5 | Horizontal Tilt |
| 6 | Common |
| 7 | Spare |
| 8 | Spare |
| 9 | Spare |
| 10 | Spare |
| 11 | Spare |

TABLE VI
POWER SUPPLIES

| <u>Supply</u> | <u>Function</u> |
|---|--------------------------------------|
| A. Power Supply No. 4 AC Input, Pins 1 and 2 +12VDC, Pin 4 -6VDC, Pin 10 Common, Pins 3 and 9 | Digital Circuits Digital Circuits |
| B. Power Supply No. 2 AC Input +24VDC | Relay Voltage |
| C. Power Supply No. 3 AC Input +400VDC | Peristaltic Actuator (Not Used) |
| D. Power Supply No. 4 AC Input, Pins 1 and 2 +1500VDC, pin 5 (common), Pin 6 | Doppler Frequency Shifter |
| E. Power Supply No. 5 AC Input +28VDC | Stepper Motor |
| F. Power Supply No. 6 +5VDC | Digital Circuits |
| G. Power Supply No. 7 ± 15 Volts | Operational Amplifiers |

TABLE VII
POTENTIOMETERS

| <u>Board</u> | <u>Resistor No.</u> | <u>Function</u> |
|--------------|---------------------|---|
| 1 | R1 | Photodiode Feedback |
| | R2 | Photodiode Feedback |
| | R3 | Photodiode Feedback |
| 2 | R15 | 90° Phase Adjustment |
| | R17 | 90° Phase Adjustment |
| 5 | R8 | Doppler Frequency Shifter, Frequency Adjust |
| | R3 | Doppler Frequency Shifter, Amplitude Adjust |
| | R25 | DVM Scale Adjust, Figure Error |
| 6 | RH | DVM Scale Adjustment, Horiz Error |
| 7 | RV | DVM Scale Adjustment, Vert Error |
| 8 | R17 | Threshold Level Adjustment |
| 9 | R17 | Threshold Level Adjustment |
| 13 | R3 | Sweep Rate Adjustment |
| 14 | R10 | Gain Adjustment |
| | R11 | Zero Check Rate Adjust. |
| 15 | R9 | Scan Rate Adjustment |

Switches

| | | |
|-----|----------|---------------------------------|
| SW1 | 5 Vdc | Digital Circuits |
| SW2 | 1500 Vdc | Doppler Frequency Shifter |
| SW3 | 400 Vdc | Peristaltic Actuator (Not Used) |
| SW4 | 28 V | Stepper Motor |